BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Planet Illumination During Manned Planetary Encounter Missions
Case 233

DATE: August 23, 1967

FROM: C. L. Greer

ABSTRACT

Current manned planetary program studies include consideration of the following encounter missions: 1975 Mars, 1977 triple planet (Venus-Mars-Venus) and 1978 dual planet (Venus-Mars). The planet illumination during the encounter phases of each of these missions is examined to determine 1) suitability for conducting experimental probe operations and 2) constraints that may be imposed on operations. The results show that visual targeting of probes at Mars is feasible with the possible exception of the 1978 mission. MSSR probes for the 1977 and 1978 missions must be designed for long surface lifetime or operation in darkness. The illumination of Venus reveals the position of the subsolar and anti-solar regions. If probe entry angles are limited to the 10-30° range, the subsolar region may not be accessible to probes on the second Venus encounter of the 1977 mission or the 1978 mission. The anti-solar region appears accessible to probes on the 1977 mission but not on the 1978 mission.

(NASA-CR-154792) LANET ILLUMINATION DURING MANNED PLANETARY ARY NCOUNTER MISSIONS (Bellcomm, Inc. Inc.) 28 p

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MEMORANDUM FOR FILE

INTRODUCTION

Current manned planetary program studies include consideration of the following encounter missions: 1975 Mars, 1977 triple planet (Venus-Mars-Venus) and 1978 dual planet (Venus-Mars). The purpose of this memorandum is to examine the planet illumination during the encounter phases of each of these missions in order to determine 1) suitability for conducting experimental probe operations and 2) constraints that may be imposed on the probe system requirements. Incident to the necessary analysis, additional trajectory data were determined and recorded here for reference purposes.

MISSION PARAMETERS

The missions analyzed are those selected by the planetary Joint Action Group (JAG) as their baseline missions. They are assumed to be representative of the classes of trajectories from which they were chosen. However, with a wide range of launch dates and planet encounter dates this may not be the case. The specific missions evaluated are:

1975 Mars

Earth launch	September 23, 1975
Mars encounter	January 31, 1976
Earth entry	July 22, 1977

1977 Triple Planet

Earth launch	January 23, 1977
Venus encounter	June 21, 1977
Mars encounter	January 3, 1978
Venus encounter	August 20, 1978
Earth entry	January 9, 1979

1978 Dual Planet

Earth launch	December 8, 1978
Venus encounter	May 15, 1979
Mars encounter	January 2, 1980
Earth entry	September 13, 1980

TRAJECTORY DATA

In order to determine the encounter geometry a computer program was written by the author. The program determines the illumination of the planet on arrival and departure, the spacecraft trajectory in the flyby plane and the variations of sun angle (sun-planet-spacecraft angle), flight path angle, time from periapsis, distance from the center of the planet and velocity of the spacecraft. The output data from the computer program are presented in Figures 1-1 through 3-7.

The graphic presentation of each mission has the same format. The first diagram shows the heliocentric trajectories of the spacecraft, Mars, Earth, Venus and Mercury as viewed from the normal to the ecliptic plane. To simplify plotting, all trajectories are plotted without regard for the angle of inclination to the ecliptic plane.

For each planet encounter there are three figures. The first is a view of the hyperbolic flyby plane as seen from the normal to the flyby plane. In addition to the solar illumination of the planet, the view of the hyperbolic flyby plane shows the arrival asymptote, departure asymptote, periapsis position and the flyby trajectory. The second diagram shows the planet as seen from the arrival and departure asymptotes. The "arrival-departure" views also show the flyby trace on the planet. The third figure contains the following parameters as a function of true anomaly: 1) time from periapsis; 2) distance from the center of the planet; 3) sun angle on arrival; 4) sun angle on departure; 5) flight path angle; and 6) velocity of the spacecraft. The diagrams of the planets show the location of the terminator, the equator, the pole which is visible, the subsolar (anti-solar) point if visible and the sub-Earth (anti-Earth) point.

The position of the planet with respect to the sun was assumed to be fixed in the encounter results presented. Thus, there is a small error in the position of the terminator and the sun-planet-spacecraft angles. However, for this analysis the motion of the planet is negligible when compared to the motion of the spacecraft.

1975 ENCOUNTER MISSION

The fully sunlit planet on spacecraft arrival (Figure 1-3) is characteristic of the twilight encounter missions. The spacecraft passes over the northern hemisphere as shown by the flyby trace, with periapsis occurring 14° behind the terminator. The sun angle on approach is about 6° (Figure 1-4). For comparison, photos three and four taken by Mariner IV had a sun angle of about 10°. The landing site of the Mars Surface Sample Return (MSSR) probe under consideration would be last viewed from the spacecraft between 12 and 15 hours prior to periapsis, corresponding to surface resolutions of 0.3 km and 0.5 km, respectively, with a one-meter diffraction limited telescope.[1] This compares with a maximum resolution of 3 km for Mariner IV. However, with the small sun angle the technique of shadow measurement may not be adequate to determine topography.

1977 TRIPLE PLANET ENCOUNTER MISSION

In the 1977 triple planet encounter the two Venus encounters are similar. The angles of inclination to the Venus orbit plane are 80.4° and 80.5°, respectively, and both trajectories pass over the south polar region. On the first encounter periapsis occurs on the sunlit side of the planet and for the second, on the darkside. The periapsis altitudes are 680 km and 700 km, respectively (Figures 2-2 and 2-8).

The subsolar and anti-solar regions are the areas of greatest scientific interest at Venus. If probe entry angles are limited to the 10-30° range, approximately one-third of the planet is accessible to probes.[2] For the first encounter, probes could be targeted to both regions of greatest scientific interest. However, in this encounter the spacecraft has line-of-sight contact with the subsolar point (sun-planet-spacecraft angle <90°) for only 1.5 hours (Figure 2-4). The second encounter has line-of-sight contact with the subsolar point on arrival and the anti-solar point on departure (Figure 2-10), but the subsolar region may not be accessible.

The Mars encounter has a periapsis radius of 3960 km on the darkside of the planet. In this instance the two proposed MSSR's[3] must be designed to operate in the darkness or designed for long surface lifetime if they are to operate in sunlight. The MSSR's on this mission would require less propulsion capability than the 1975 mission MSSR since the velocity of the spacecraft is about one-half that of the 1975 Mars encounter mission. However, the requirement for operating in the darkness or with a long surface lifetime may increase the weight requirement over what has been previously estimated.

The MSSR landing site would be last viewed between 12 and 15 hours prior to periapsis at surface resolutions of approximately 0.2 km. Shadows occurring within 20° of the terminator would be visible. Hence, shadow measurement may be used to determine topography.

1978 DUAL PLANET ENCOUNTER MISSION

In this mission the flyby plane has an angle of inclination of 12.2° with respect to the Venus orbit plane during the Venus encounter. The spacecraft has line-of-sight contact with the subsolar point on approach and the anti-solar point on departure. However, as in the second Venus encounter on the 1977 mission, these regions may not be accessible to the probes.

The Mars encounter is from the darkside of the planet with almost three-fourths of the planet in darkness. The resolution of a one-meter diffraction limited telescope is approximately 0.2 km at 12 hours before periapsis, but there may be a problem in visual targeting of probes since so much of the planet is in darkness. The spacecraft passes over the dark limb of the planet with periapsis 36° behind the terminator. The MSSR's for this mission must be designed for operation in the darkness or long surface lifetime as was the case for the 1977 triple planet mission.

CONCLUSION

Analysis of the planet illumination during the encounter phase of manned planetary encounter missions assumed as baseline missions by the JAG yields the following conclusions:

a) The 1975 Mars encounter mission is generally suitable for probe targeting. The sun angle on arrival, however, may be too low for the use of the shadow measurement technique to determine topography.

b) The first Venus encounter on the 1977 triple planet mission permits targeting probes to the subsolar and anti-solar regions. On the second Venus encounter the subsolar region may not be accessible. The Mars encounter has a sun angle of approximately 90° on approach so shadow measurement may be used to determine topography. The MSSR probe must be designed for operation in darkness or long surface lifetime.

c) The flyby plane of the Venus encounter on the 1978 dual planet mission has a low angle of inclination which permits extended line-of-sight contact with the subsolar and anti-solar regions. However, these regions may not be accessible to probes. The Mars encounter has poor solar illumination and visual targeting of probes may not be possible. The MSSR must be designed for operation in darkness or long surface lifetime.

Acknowledgement: The trajectory data used in computing the heliocentric trajectories and the hyperbolic encounter trajectories were received from A. A. VanderVeen of Bellcomm.

C. L. Greer

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Attachment
Figures 1-1 to 3-7

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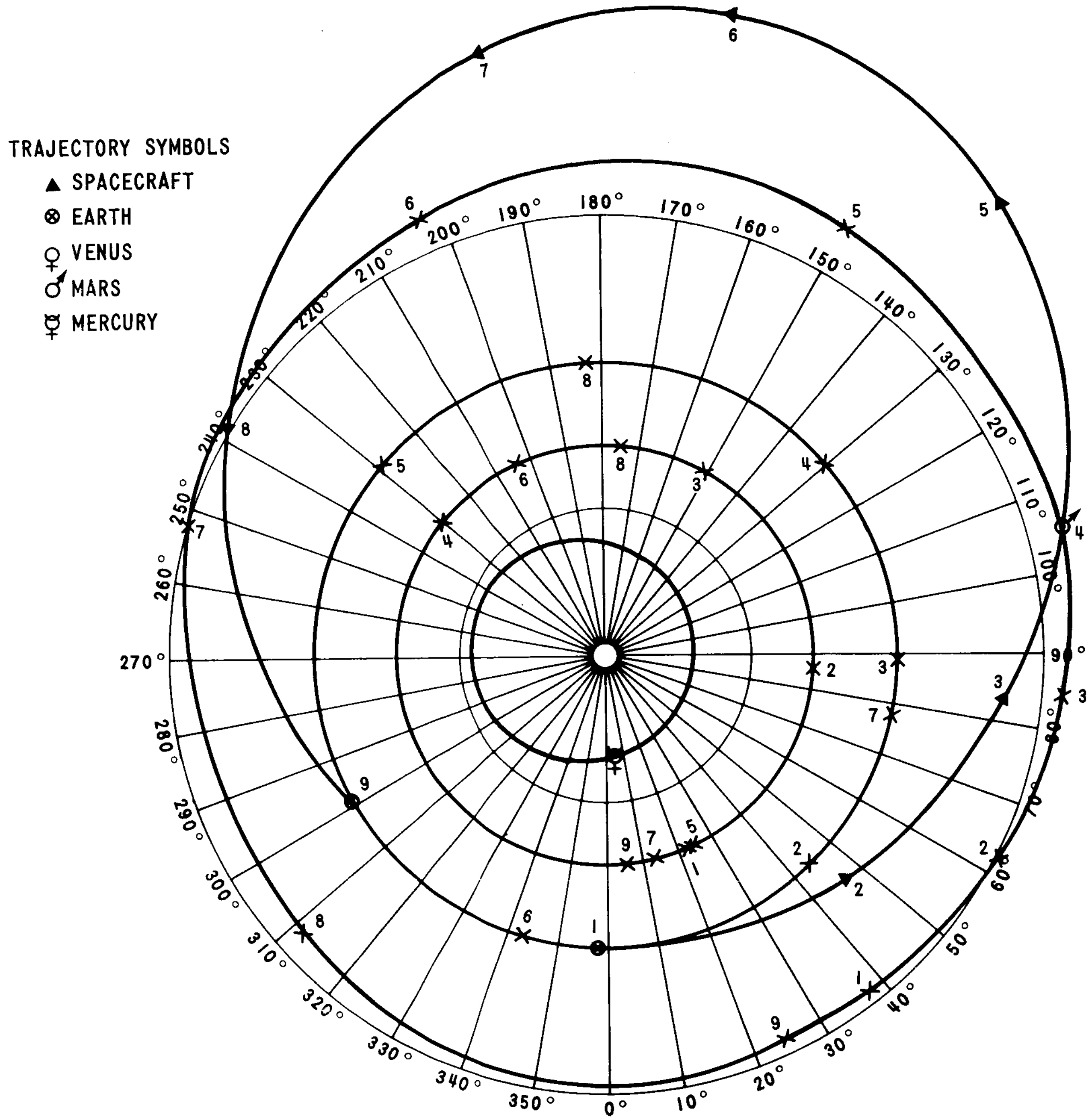
REFERENCES

(1) W. B. Thompson et al, "Experiment Payloads for a Manned Mars Flyby Mission," Bellcomm TR-67-233-1, May 15, 1967.

(2) J. J. Schoch, "1975 Venus Lightside Flyby Trajectory of Spacecraft and Probe," Bellcomm Memorandum for File, June 7, 1967.

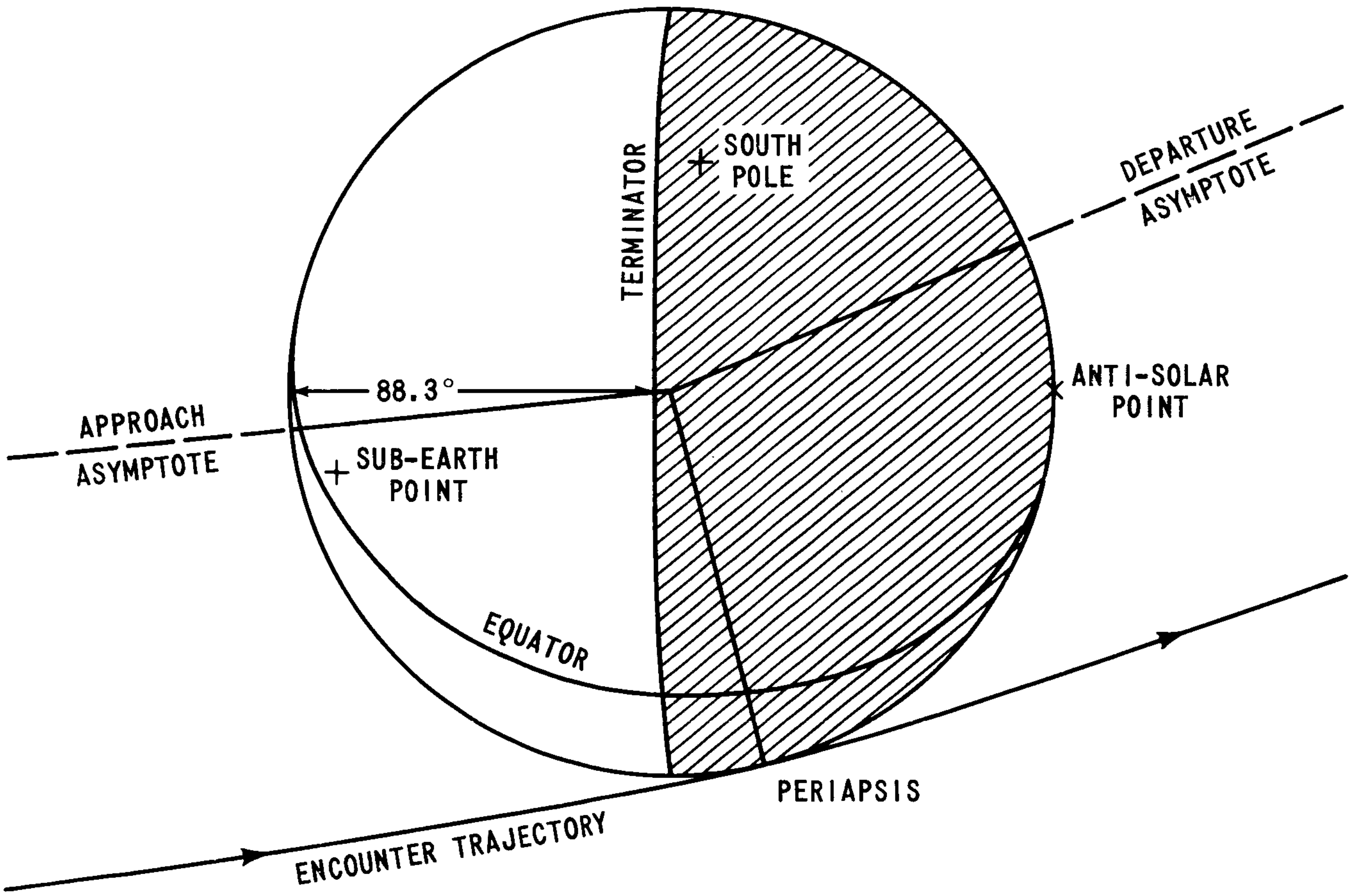
(3) W. B. Thompson, private communication, July 19, 1967.



	DAYS INTO MISSION	POSITION NUMBER
0		1
45		2
90		3
130	(MARS ENCOUNTER)	4
230		5
348	(APHELION)	6
448		7
548		8
648	(EARTH ENTRY)	9

FIGURE 1-1 - 1975 MARS MISSION

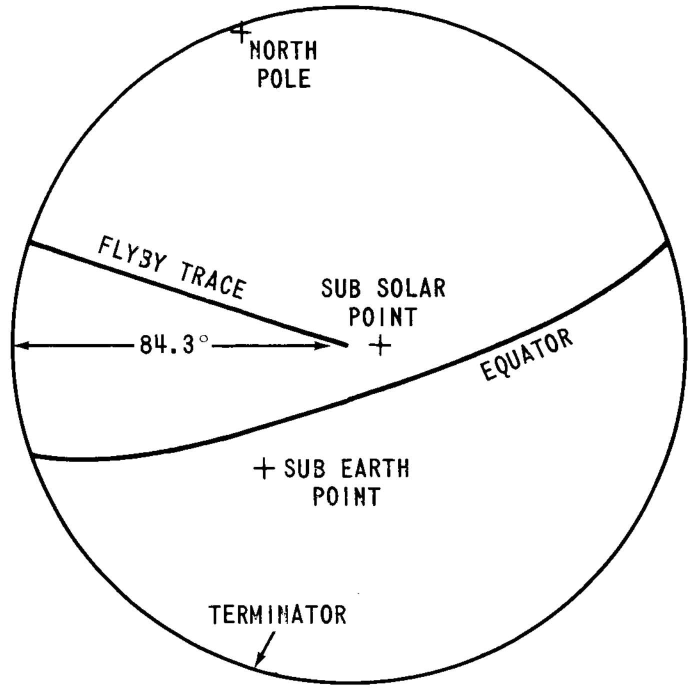
MARS PASSAGE DATE	1/31/76
MARS PASSAGE DISTANCE	18 KM
ARRIVAL-DEPARTURE V_{∞}	8.6 KM/SEC
VELOCITY AT PERIAPSIS	9.95 KM/SEC



INCLINATION OF FLYBY PLANE TO
MARS EQUATORIAL PLANE 142.6°

MARS ENCOUNTER

FIGURE 1-2 - 1975 MARS MISSION



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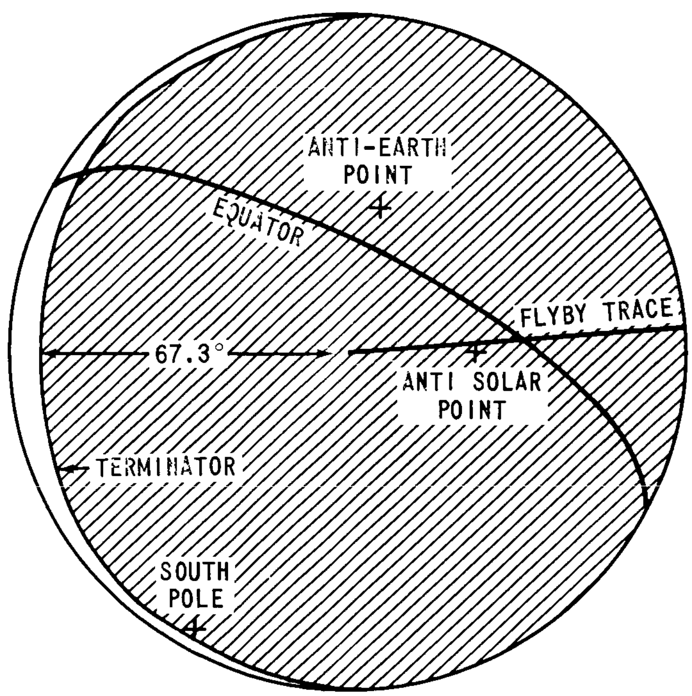
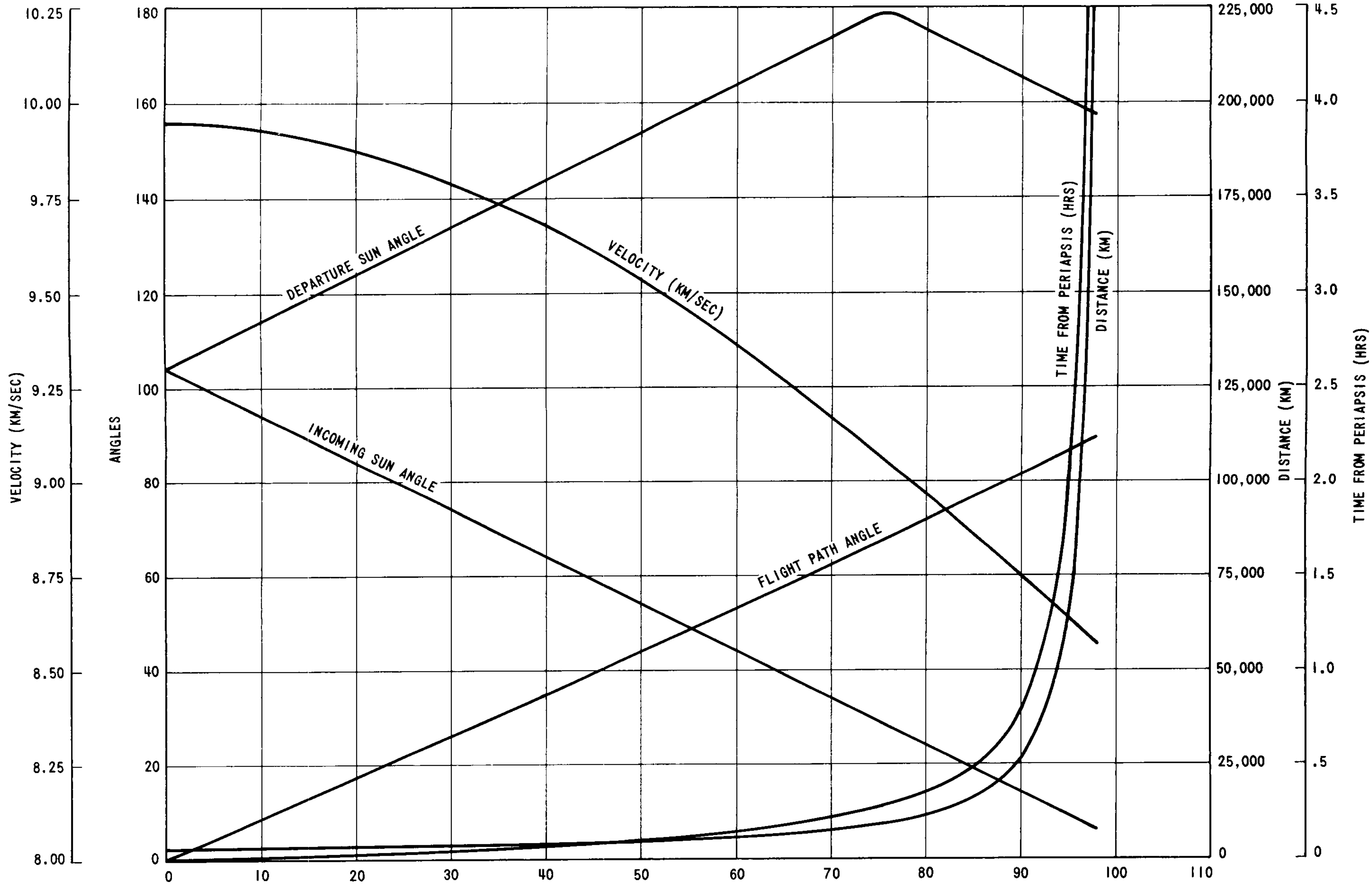


VIEW ON DEPARTURE

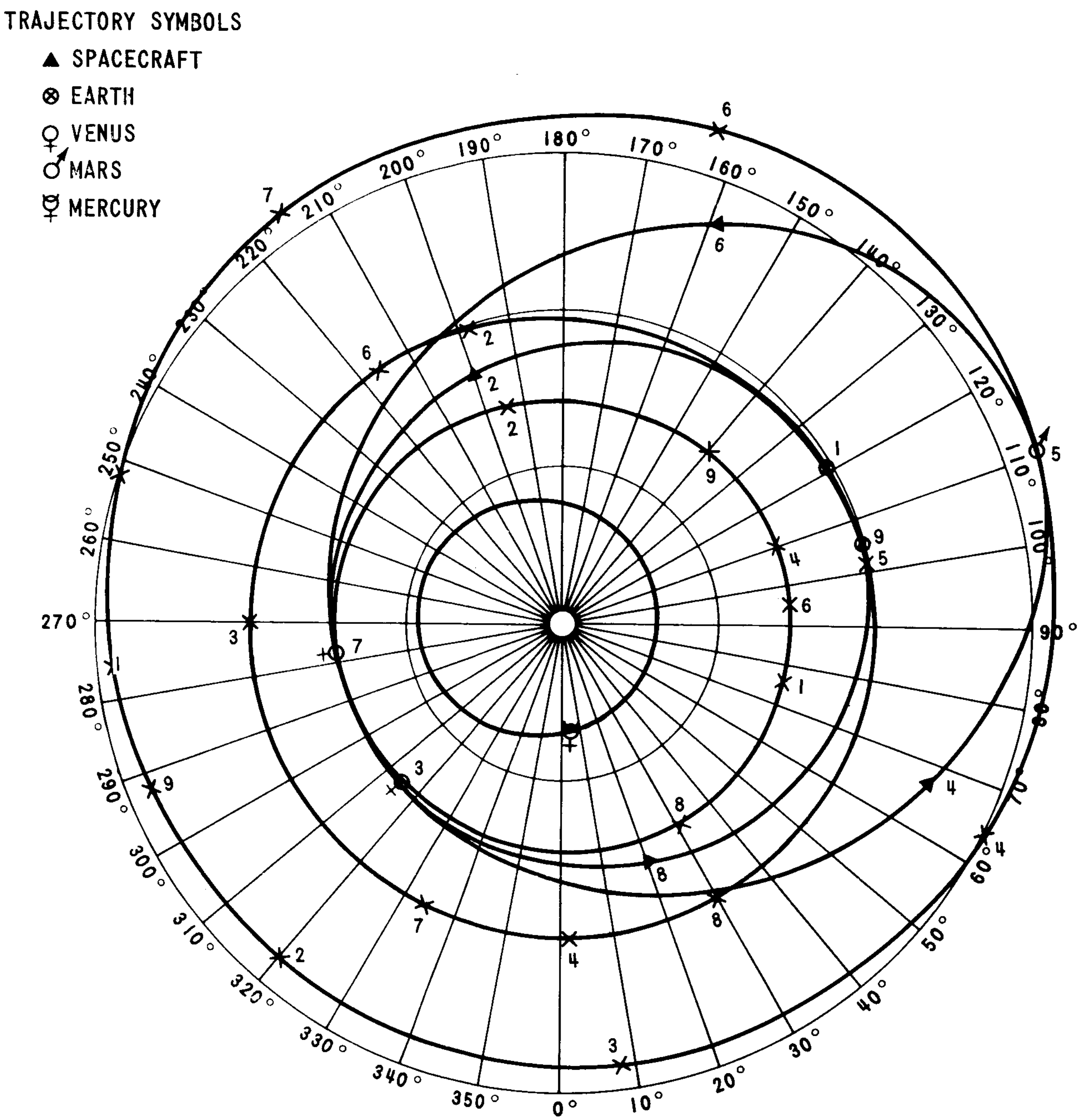
MARS ENCOUNTER

FIGURE I-3 - 1975 MARS MISSION



MARS ENCOUNTER

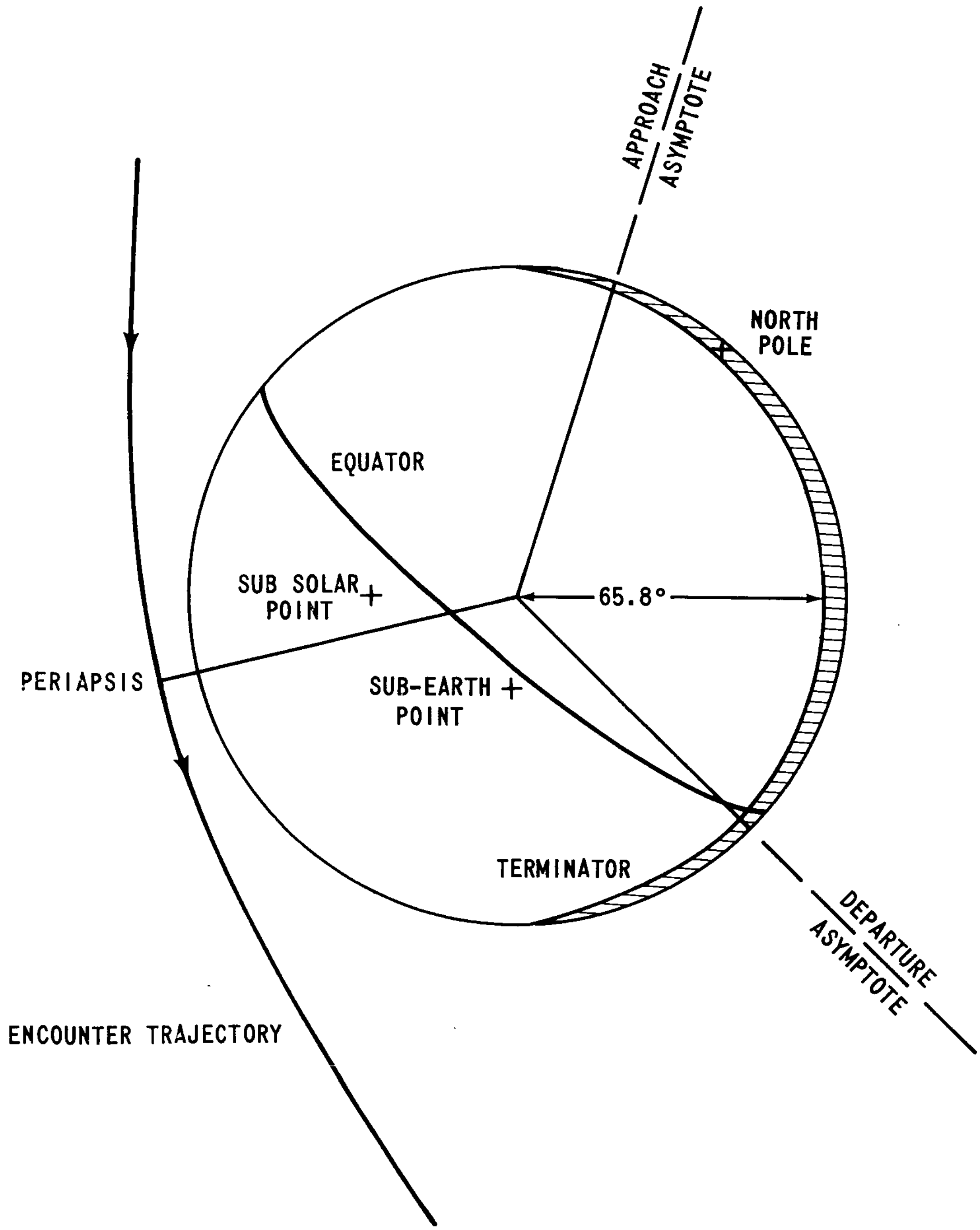
FIGURE I-4 - 1975 MARS MISSION



DAYS INTO MISSION	POSITION NUMBER
0	1
74	2
149 (VENUS ENCOUNTER)	3
245	4
345 (MARS ENCOUNTER)	5
459	6
574 (VENUS ENCOUNTER)	7
645	8
716 (EARTH ENTRY)	9

FIGURE 2-1 - 1977 TRIPLE PLANET MISSION

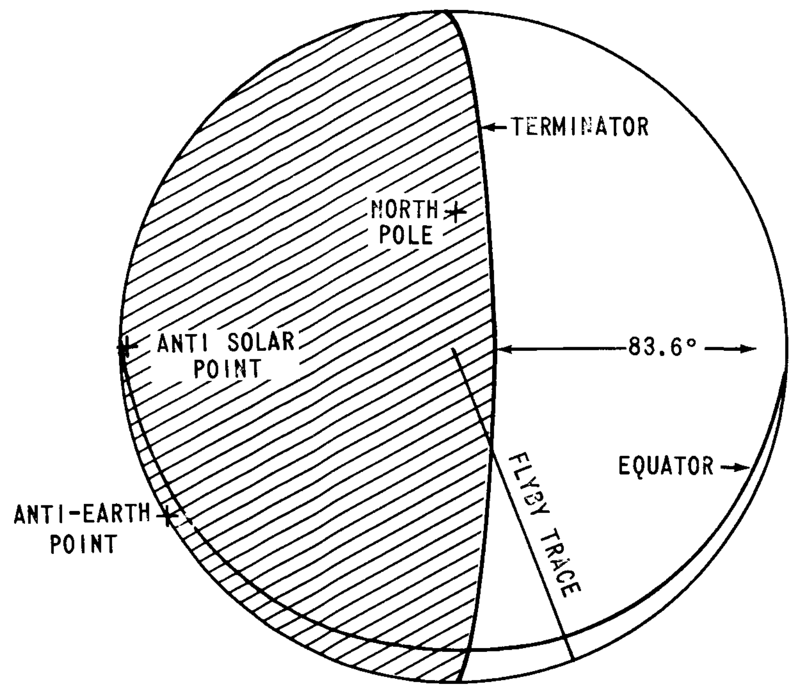
VENUS PASSAGE DATE	6/21/77
VENUS PASSAGE DISTANCE	680 KM
ARRIVAL - DEPARTURE V_∞	6.7 KM/SEC
VELOCITY AT PERIAPSIS	11.8 KM/SEC



INCLINATION OF FLYBY PLANE TO
VENUS EQUATORIAL PLANE 80.4°

FIRST VENUS ENCOUNTER

FIGURE 2-2 - 1977 TRIPLE PLANET MISSION



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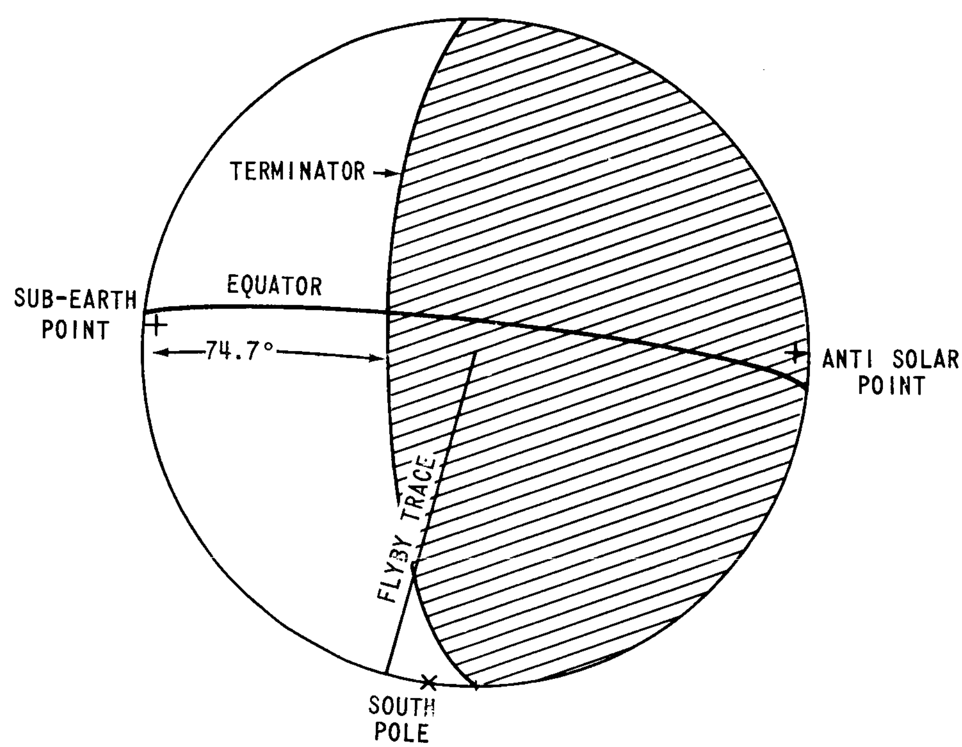
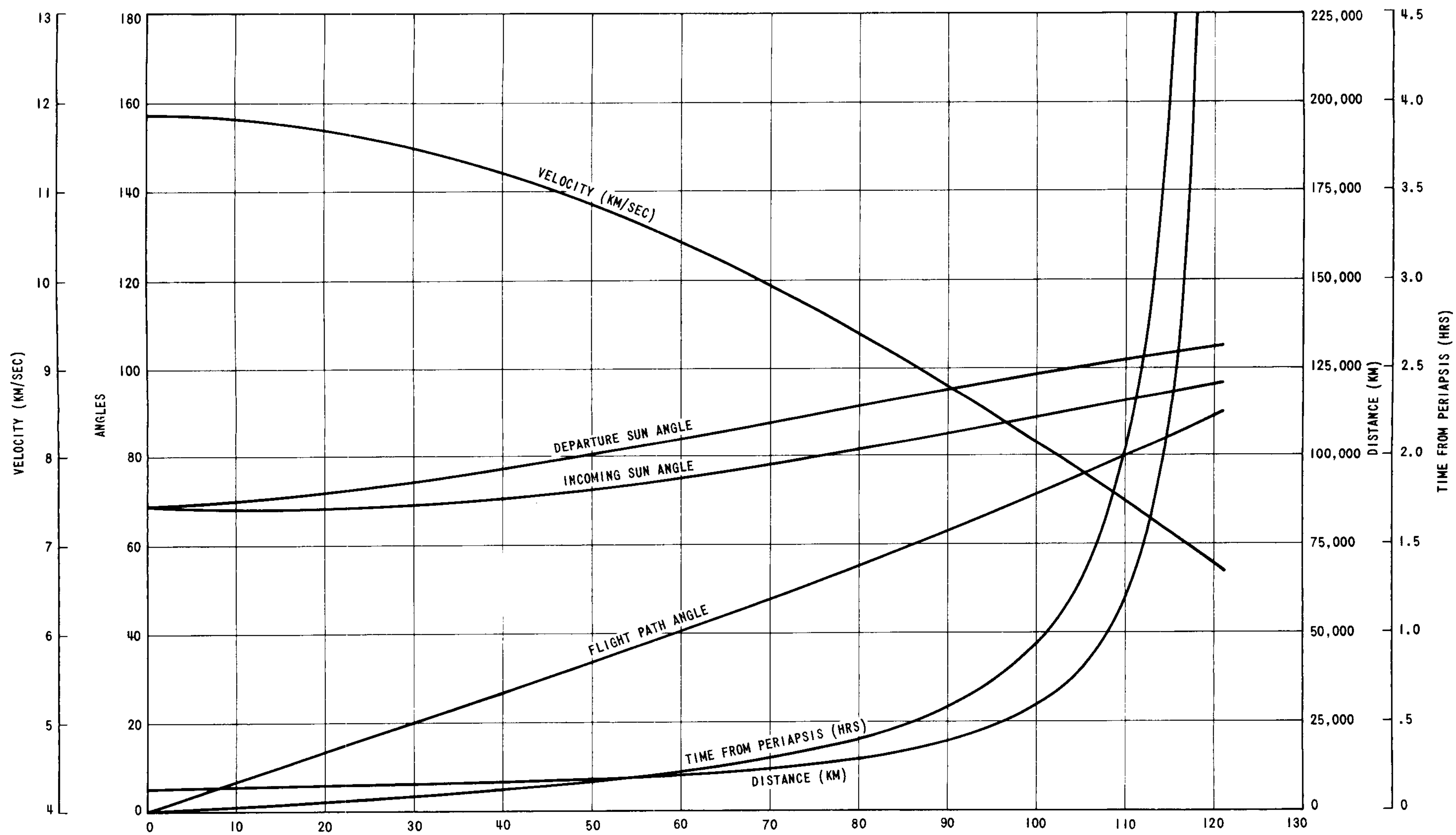


VIEW ON DEPARTURE

FIRST VENUS ENCOUNTER

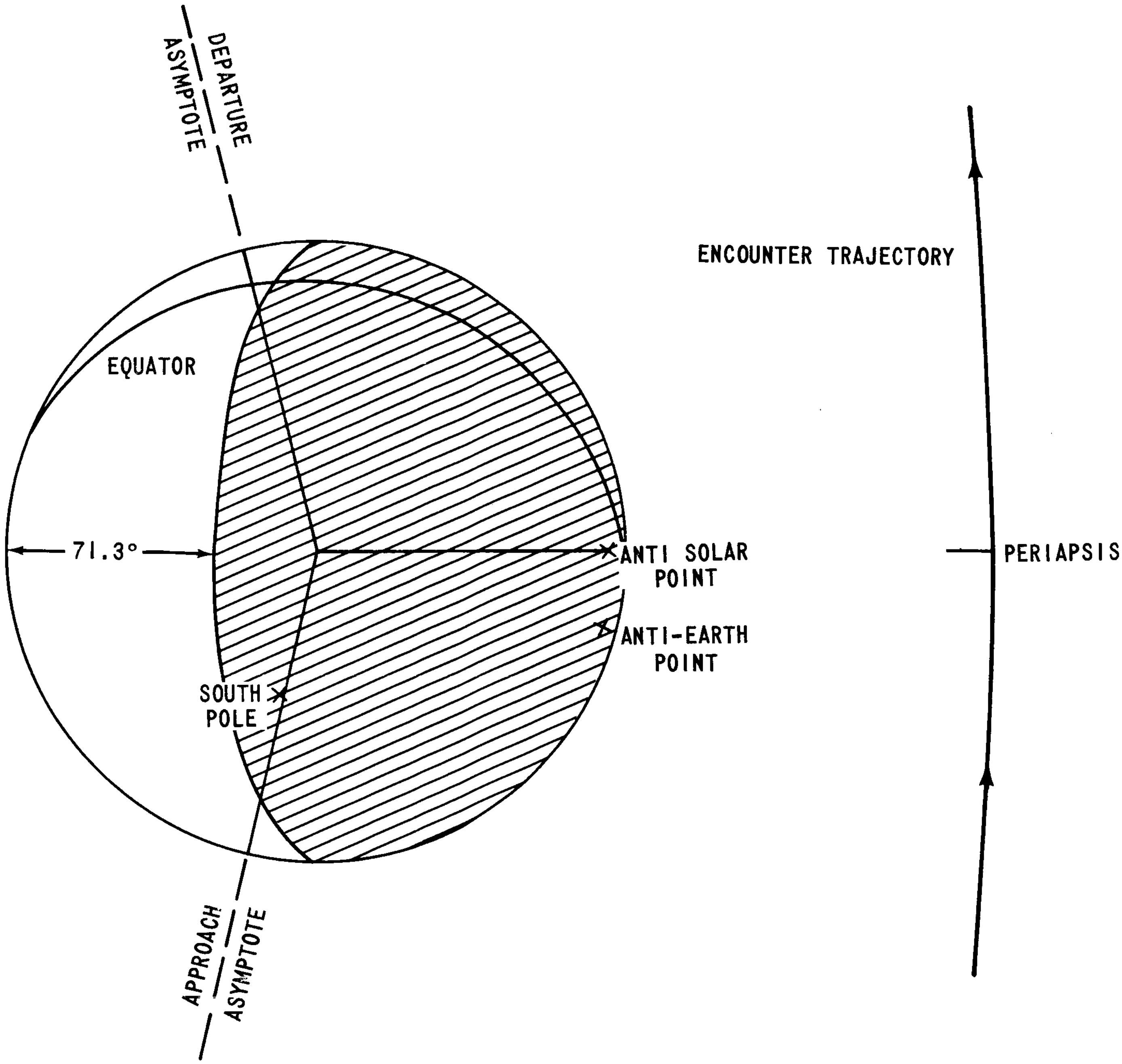
FIGURE 2-3 - 1977 TRIPLE PLANET MISSION



FIRST VENUS ENCOUNTER

FIGURE 2-4 - 1977 TRIPLE PLANET MISSION

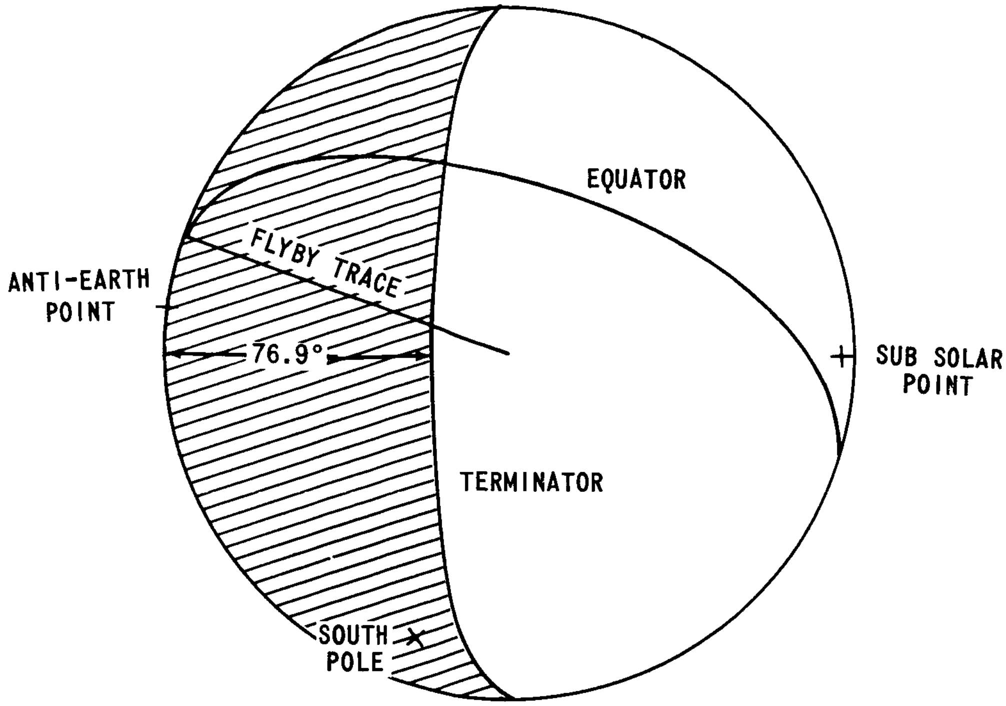
MARS PASSAGE DATA	1/3/78
MARS PASSAGE DISTANCE	3960 KM
ARRIVAL - DEPARTURE V_∞	4.4 KM/SEC
VELOCITY AT PERIAPSIS	5.6 KM/SEC



INCLINATION OF FLYBY PLANE TO
MARS EQUATORIAL PLANE - 60.3°

MARS ENCOUNTER

FIGURE 2-5 - 1977 TRIPLE PLANET MISSION



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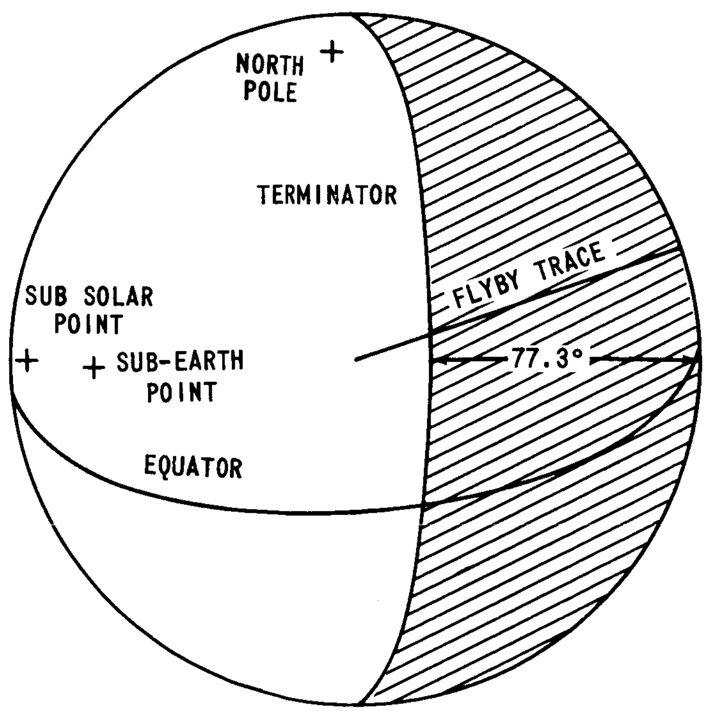
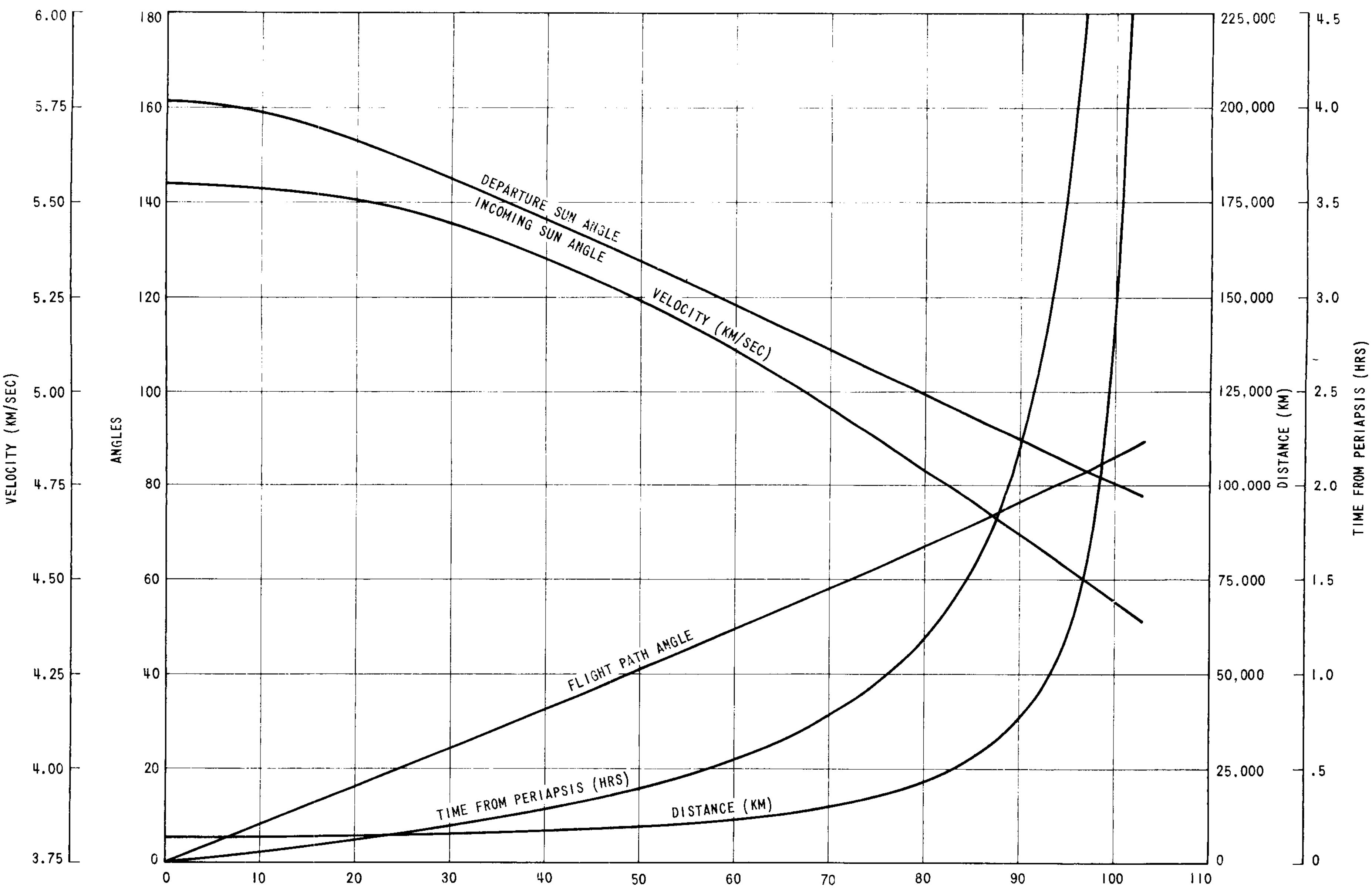


VIEW ON DEPARTURE

MARS ENCOUNTER

FIGURE 2-6 - 1977 TRIPLE PLANET MISSION

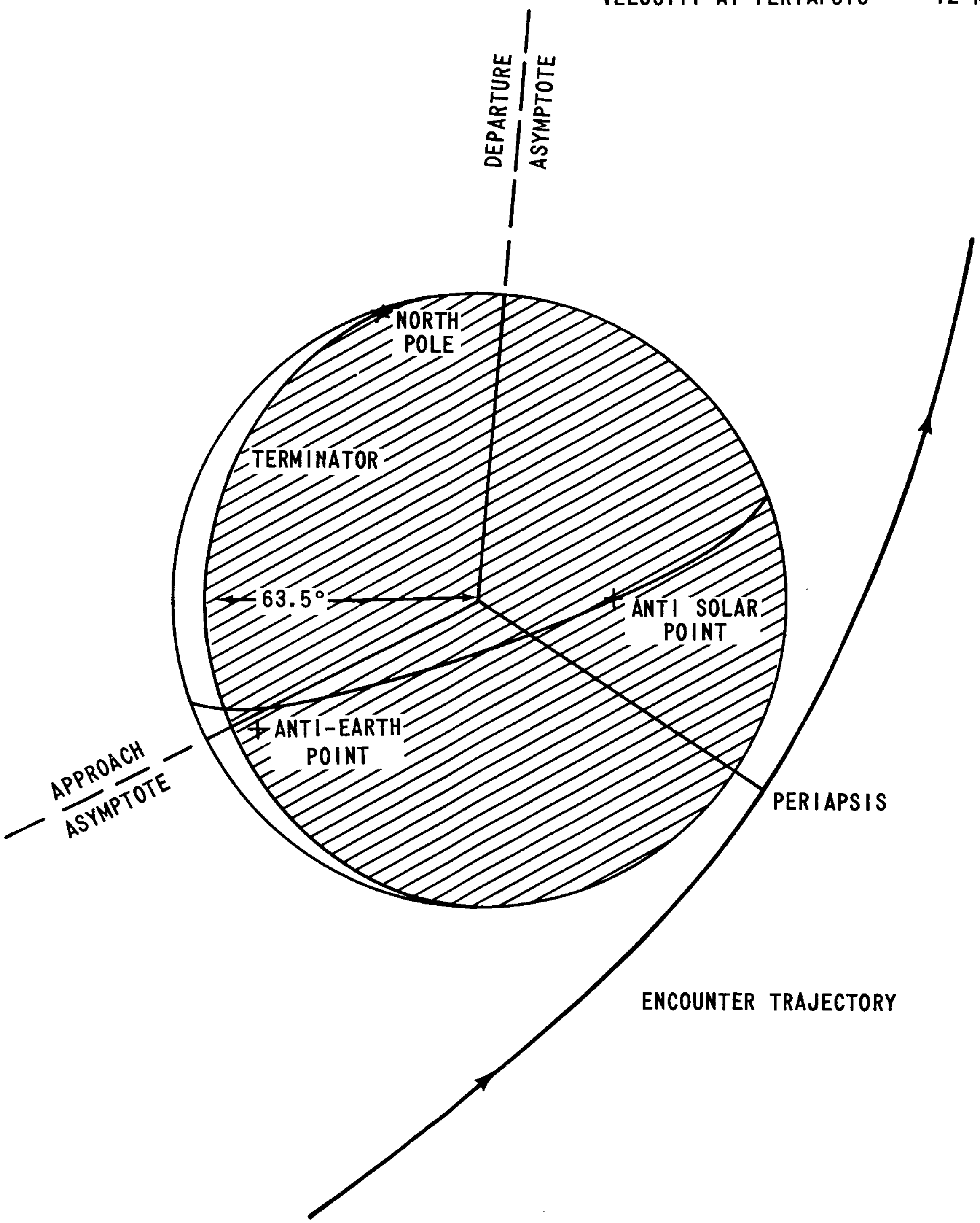


TRUE ANOMALY (DEGREES)

MARS ENCOUNTER

FIGURE 2-7 - 1977 TRIPLE PLANET MISSION

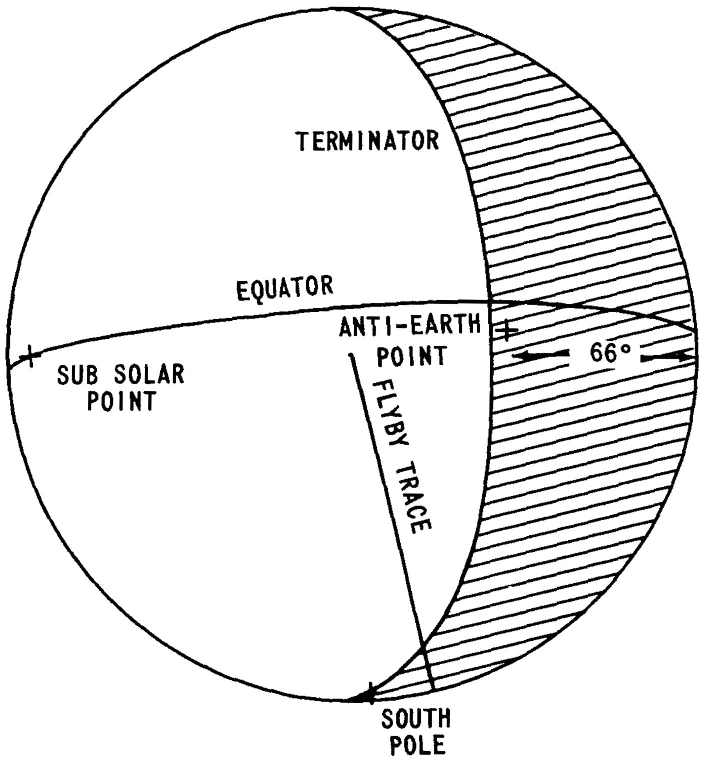
VENUS PASSAGE DATE	8/20/78
VENUS PASSAGE DISTANCE	700 KM
ARRIVAL - DEPARTURE V_{∞}	7.1 KM/SEC
VELOCITY AT PERIAPSIS	12 KM/SEC



INCLINATION OF FLYBY PLANE TO
VENUS EQUATORIAL PLANE - 80.5°

SECOND VENUS ENCOUNTER

FIGURE 2-8 - 1977 TRIPLE PLANET MISSION



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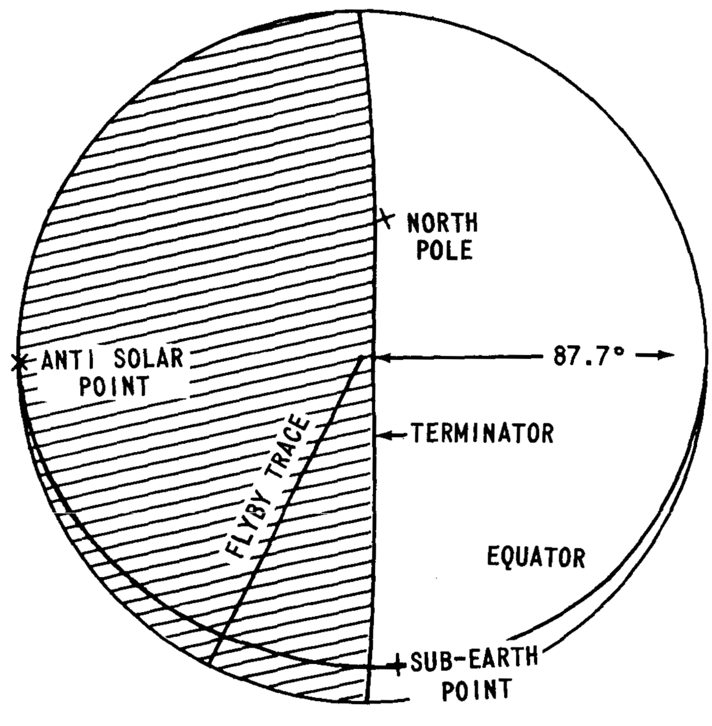
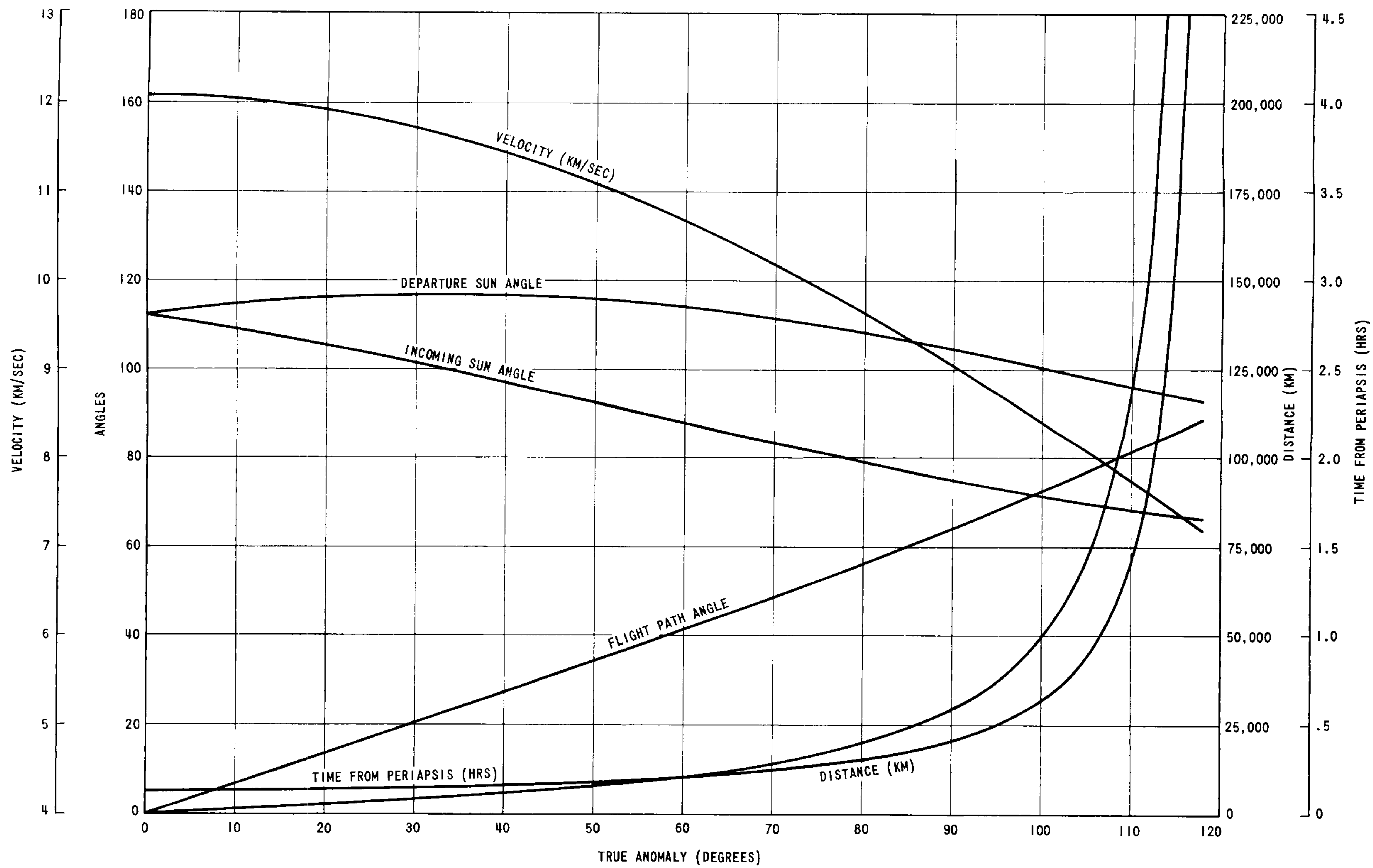


VIEW ON DEPARTURE

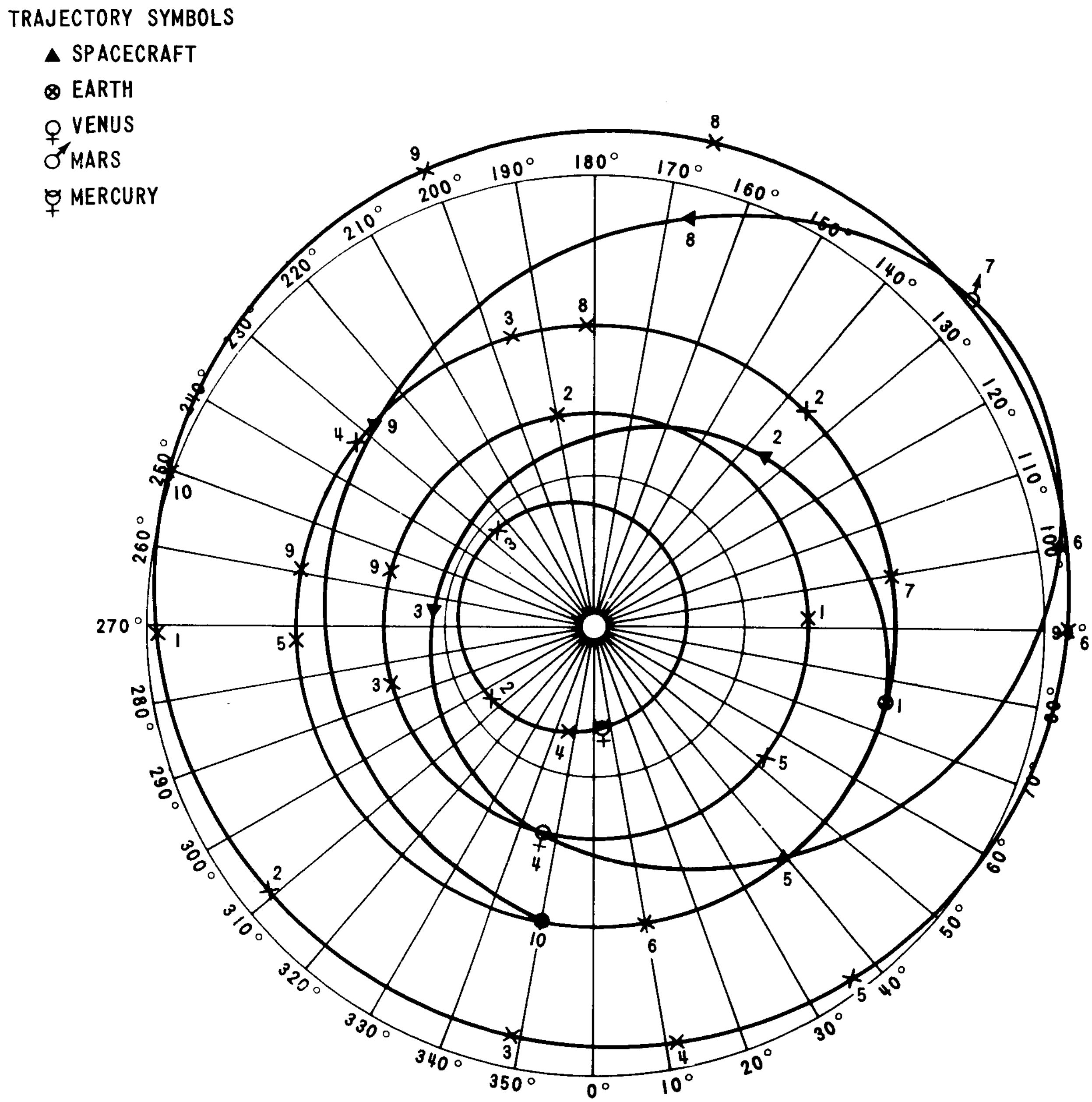
SECOND VENUS ENCOUNTER

FIGURE 2-9 - 1977 TRIPLE PLANET MISSION



SECOND VENUS ENCOUNTER

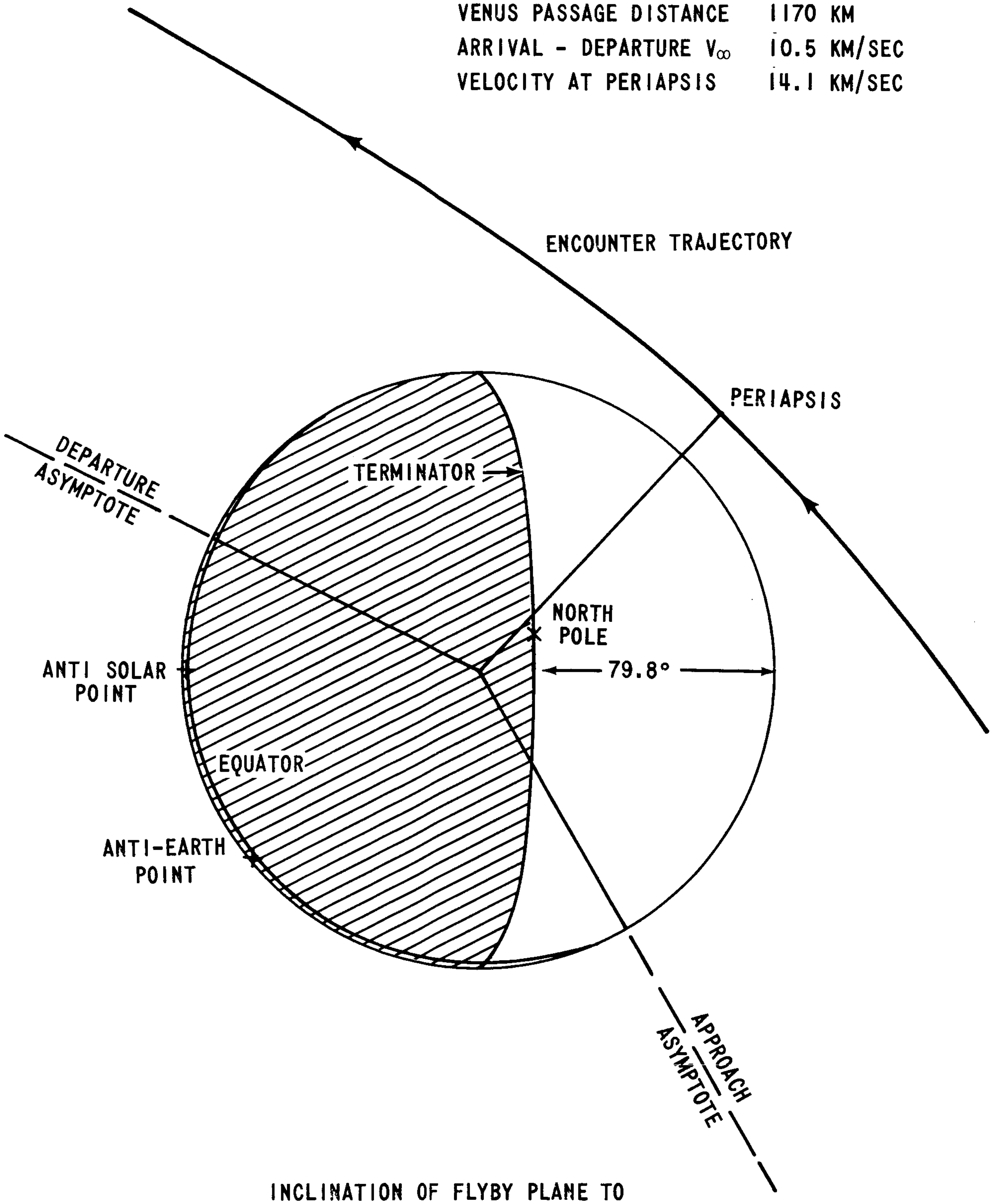
FIGURE 2-10 - 1977 TRIPLE PLANET MISSION



DAYS INTO MISSION	POSITION NUMBER
0	1
60	2
120	3
158 (VENUS ENCOUNTER)	4
200	5
300	6
390 (MARS ENCOUNTER)	7
470	8
550	9
645 (EARTH ENTRY)	10

FIGURE 3-1 - 1978 DUAL PLANET MISSION

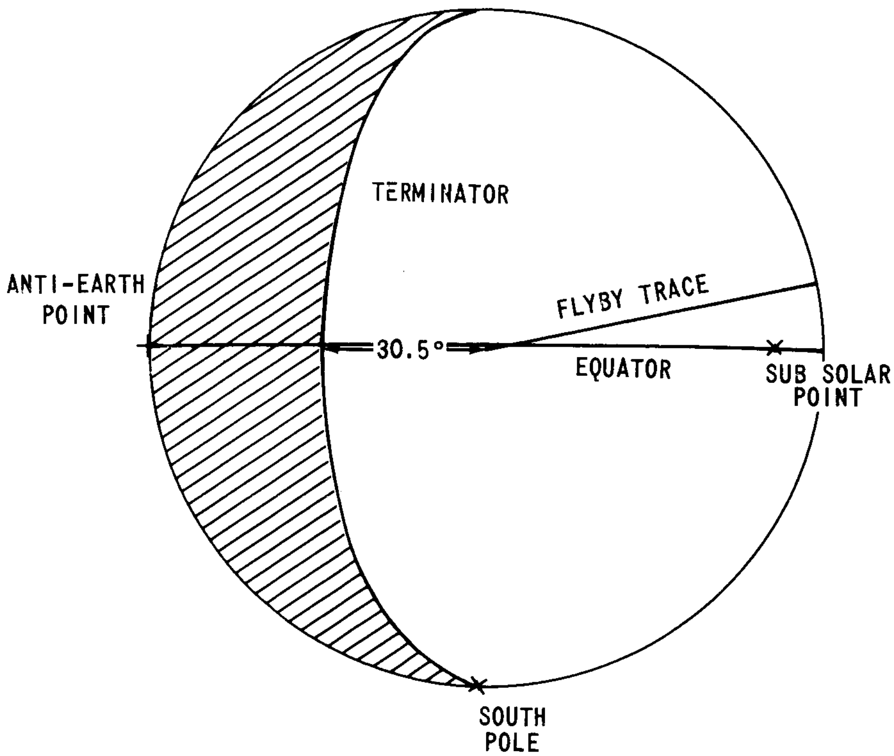
VENUS PASSAGE DATE	5/15/79
VENUS PASSAGE DISTANCE	1170 KM
ARRIVAL - DEPARTURE V_∞	10.5 KM/SEC
VELOCITY AT PERIAPSIS	14.1 KM/SEC



INCLINATION OF FLYBY PLANE TO
VENUS EQUATORIAL PLANE - 12.2°

VENUS ENCOUNTER

FIGURE 3-2 - 1978 DUAL PLANET MISSION



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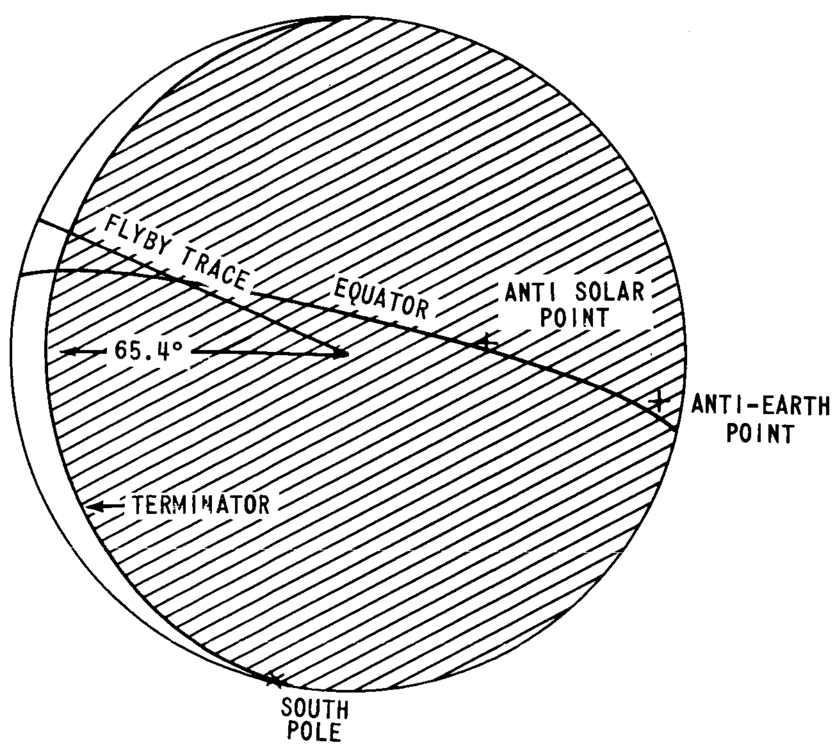
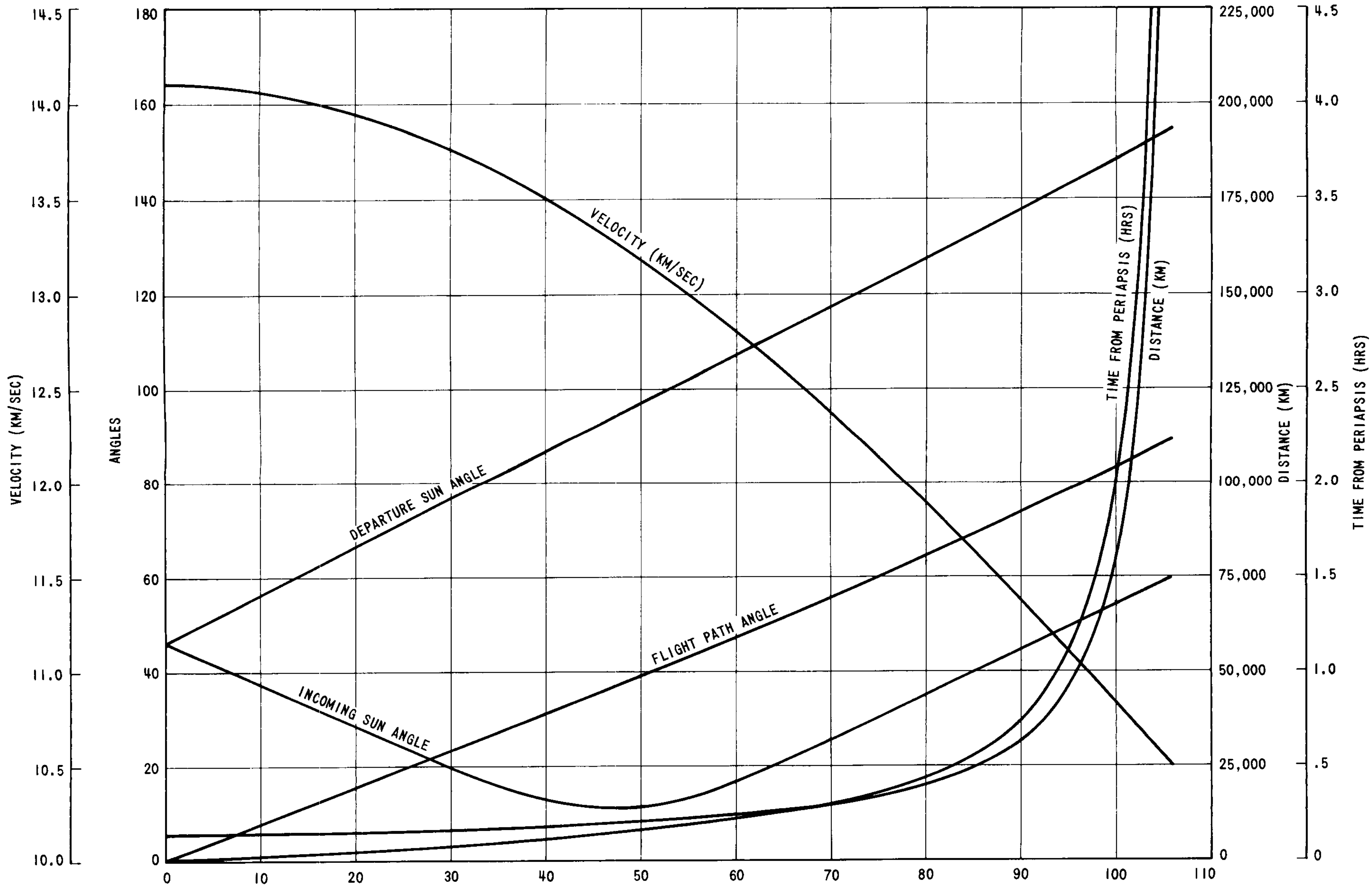


VIEW ON DEPARTURE

VENUS ENCOUNTER

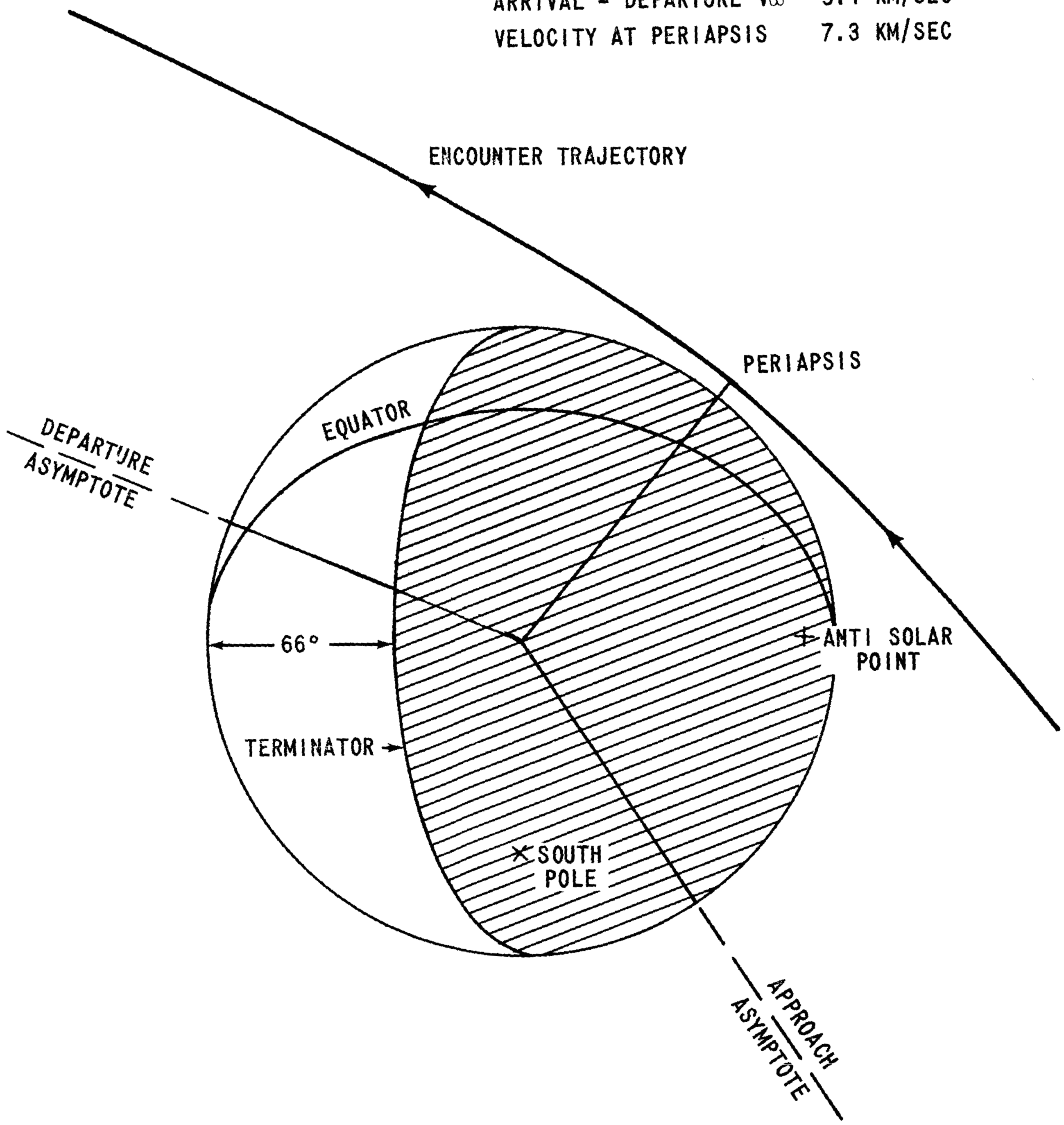
FIGURE 3-3 - 1978 DUAL PLANET MISSION



VENUS ENCOUNTER

FIGURE 3-4 - 1978 DUAL PLANET MISSION

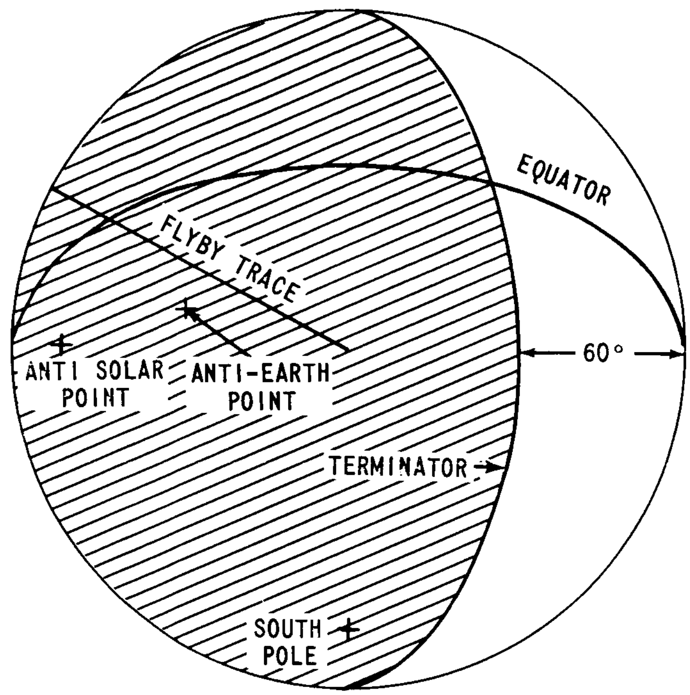
MARS PASSAGE DATE	1/2/80
MARS PASSAGE DISTANCE	200 KM
ARRIVAL - DEPARTURE V_∞	5.4 KM/SEC
VELOCITY AT PERIAPSIS	7.3 KM/SEC



INCLINATION OF FLYBY PLANE TO
MARS EQUATORIAL PLANE - 47.8°

MARS ENCOUNTER

FIGURE 3-5 - 1978 DUAL PLANET MISSION



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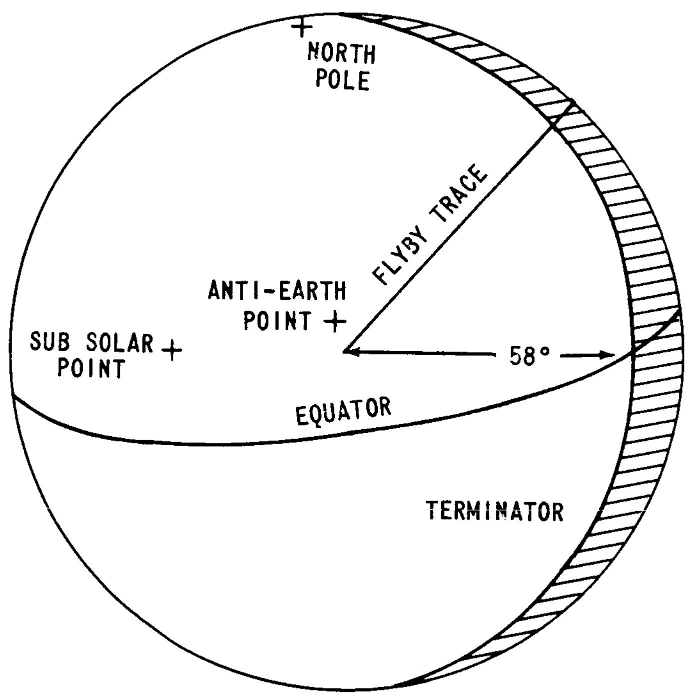
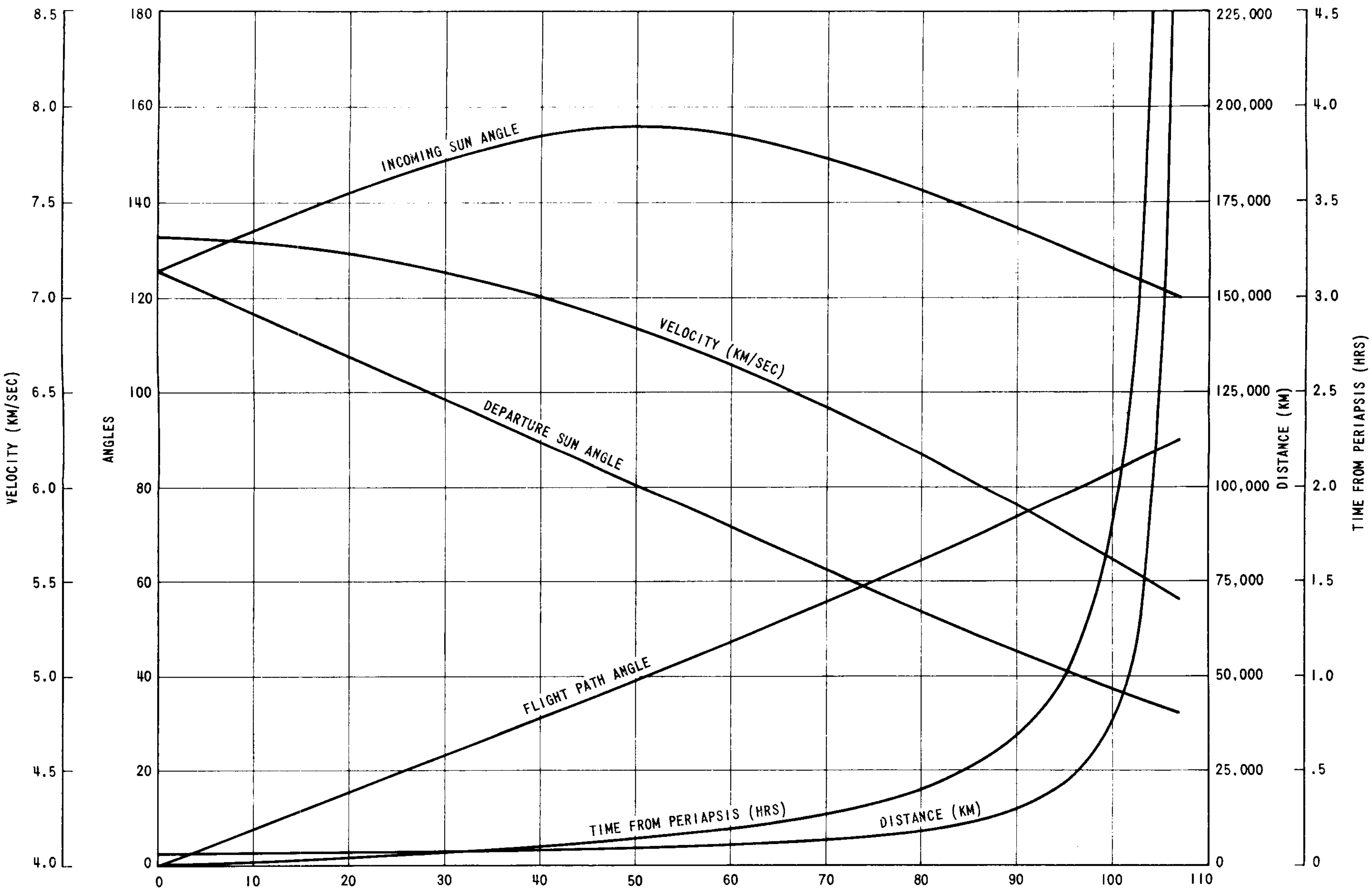


VIEW ON DEPARTURE

MARS ENCOUNTER

FIGURE 3-6 - 1978 DUAL PLANET MISSION



TRUE ANOMALY (DEGREES)

MARS ENCOUNTER

FIGURE 3-7 - 1978 DUAL PLANET MISSION

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Subject: Planet Illumination During Manned Planetary Encounter Missions Case 233

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